Vermont Flood Plain Management Services

Dam-Break Flood Analysis Upper Hurricane Reservoir Hartford, Vermont

January 1995

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The purpose of this study was to determine the downstream hazard potential of the Upper Hurricane Reservoir in Hartford, Vermont. The work was completed for the Vermont Department of Environmental Conservation's Dam Safety Program. Various dam-break flood conditions were modeled and inundation maps developed. Based on this analysis the dam is rated a Class 2 or "significant" hazard category in terms of its potential to cause downstream damage. Introductory information was also developed to aid in the development of an Emergency Plan in the event of an impending dam failure.

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UPPER HURRICANE RESERVOIR
HARTFORD, VERMONT

DAM-BREAK
FLOOD ANALYSIS

Prepared for

State of Vermont
Department of Environmental Conservation
Dam Safety Program

Prepared by

U.S. Army Corps of Engineers
New England Division

January 1995

UPPER HURRICANE RESERVOIR
DAM-BREAK FLOOD ANALYSIS
TABLE OF CONTENTS

LIST OF TABLES

LOWER HURRICANE RESERVOIR
DAM-BREAK FLOOD ANALYSIS

LIST OF PLATES

UPPER HURRICANE RESERVOIR
DAM-BREAK FLOOD ANALYSIS

EXECUTIVE SUMMARY

The primary purpose of this study is to determine the downstream hazard classification of Upper Hurricane Reservoir for the Dam Safety Program under jurisdiction of the State of Vermont, Department of Environmental Conservation. The secondary purpose is to provide introductory information for the dam owner to develop an Emergency Action Plan (EAP) in the event of an impending dam failure.

Dam-break flood conditions are evaluated for both sunny-day and storm-day failures. The analyzed storm events include the 100-year recurrent storm and variations of the Probable Maximum Flood (1/4, 1/2, 3/4, and full PMF). The PMF is defined as the flood resulting from the greatest theoretical depth of precipitation for a given duration that is physically possible over a given size storm area at a particular geographical location and a certain time of the year.

Inflow hydrographs and spillway hydraulic capacity are developed as a basis upon which to model the breach discharge. Peak flows are routed through the reservoir using the National Weather Service DAMBRK flood forecasting model. Breach discharge hydrographs for a sunny-day and a 1/2 PMF storm-day are routed through the downstream channel for a distance of approximately three miles below the dam. Limits of inundation are delineated in plan and profile view.

On the basis of U.S. Army Corps of Engineers guidelines for safety inspection, the dam's size classification is SMALL. On the basis of its potential to cause downstream damage, in terms of either loss of life or economic loss, Upper Hurricane Reservoir is rated Class 2 or a SIGNIFICANT hazard category.

Four major components of an EAP are discussed: monitoring, evaluation, preventive action, and warning. Official contacts are provided in the event of an impending dam failure.

UPPER HURRICANE RESERVOIR
DAM-BREAK FLOOD ANALYSIS

1. INTRODUCTION

a. Purpose. The primary purpose of this study is to determine the downstream hazard classification of Upper Hurricane Reservoir for the State of Vermont, Department of Environmental Conservation, Dam Safety Program. The classification system is the one adopted by the U.S. Army Corps of Engineers, and used by the Department of Environmental Conservation to determine inspection frequency and spillway adequacy of dams under its jurisdiction. A secondary purpose is to provide information for use by the dam owner in developing an Emergency Action Plan (EAP) in the event of an impending dam failure.

The study presents the findings for various dam-break flood conditions for Upper Hurricane Reservoir with resulting downstream effects. These findings include development of storm inflows into the pond, mechanisms which trigger failure of the dam, resulting breach discharges, delineation of downstream flood limits (inundation mapping), and determination of downstream hazard classification. This study was performed to investigate results of a hypothetical dam-break at Upper Hurricane Reservoir, and not because of any expected failure at the site.

b. Authority. This study was authorized by the Corps of Engineers Section 206 Flood Plain Management Services (FPMS) Program, at the request of the State of Vermont, Department of Environmental Conservation, and was performed by the New England Division.

c. Downstream Hazard Classification. Dams are classified according to the potential for loss of life and property damage in the areas downstream of the dams if it were to fail. The hazard classification does not refer to the condition of the dam.

The classification system used in this study has been adopted by the U.S. Army Corps of Engineers and is used by the Department of Environmental Conservation to determine inspection frequency and spillway adequacy for dams under its jurisdiction. The hazard classifications follow:

DOWNSTREAM HAZARD CLASSIFICATIONS OF DAMS

Class	Potential Hazard Category	Loss of Life (Extent of Development)	Potential Economic Loss (Extent of Development)
3	Low	None expected (No permanent structures for human habitation)	Minimal (Undeveloped, occasional structures or agriculture)
2	Significant	Few (No urban development and no more than a small number of inhabitable structures)	Appreciable (Notable agriculture, industry, or structures)
1	High	More than a few	Excessive (Extensive community, industry, or agriculture)

2. PROJECT DESCRIPTION

a. General. Upper Hurricane Reservoir is located in the town of Hartford in eastern Vermont (see plate 1). The dam, constructed around the turn of century for water supply purposes, is an earthfill embankment approximately 390 feet long (see plate 2). The maximum height to the down-stream outlet is about 34 feet (15 feet to the gravel road across the downstream face) and the crest width averages about 5 feet. The principal spillway is an earth cut in the right embankment with about a 12-foot top width and a 6-foot bottom width. The spillway channel follows the toe of the dike, crosses the gravel road, and flows into the outlet channel. The dam crest averages about elevation 1100 feet National Geodetic Vertical Datum (NGVD) and spillway crest is at 1097.5 feet NGVD. At spillway crest elevation, the normal pool area is about 2.5 acres.

b. Community Description. Upper Hurricane Reservoir is located in a densely wooded portion of Hartford, Vermont. There are several unimproved dirt roads in the upstream portions of the study reach. Hartford had a population of 9,404 recorded in the 1990 census, and has an area of about 38.83 square miles.

c. Downstream Conditions. The area being investigated for flooding potential is along a tributary to Kilburn Brook and the lower reach of the brook after the confluence with this tributary

within the town of Hartford (shown on plate 1). The area is primarily wooded with some open areas and the flood plain is generally very narrow. The downstream limit of the study is the confluence of Kilburn Brook and the Connecticut River, about 2.6 miles below the dam. Analysis of downstream conditions are based on a survey of brook cross sections conducted in May 1994 and a reconnaissance visit performed in August 1994.

Discharges from the outlet at Upper Hurricane Reservoir combine with flows from Lower Hurricane Reservoir about 0.4 mile downstream of the dam. This reach is extremely steep, dropping 200 feet in just over one-half mile before entering Simonds Reservoir, an abandoned rubble stone masonry and earthfill dam formerly used for water supply. The dam is about 170 feet long and 17 feet high. Flows exit over the wooden chute spillway and by leakage through the dam.

Just 0.3 mile further downstream is Route 5 where there are several structures. The road crossing at Route 5 is a 4.5 foot diameter circular concrete culvert with an invert at 600.8 feet NGVD. Four houses in this area have first floor elevations between 613 and 620.5 feet NGVD. Immediately downstream, a propane tank farm is only about 5 feet higher than the stream bed, however, the structures at this facility are considerably higher.

From here, the stream flows another 1.2 miles to the Connecticut River, dropping about 250 feet over its course and the valley becomes somewhat wider in this reach. It passes under Interstate 91, flows through a 7 foot diameter circular concrete culvert at River Road, then flows under the Central Vermont Railroad before discharging into the Connecticut River.

3. DAM DESCRIPTION

a. Identification. Upper Hurricane Reservoir is identified by the Vermont Department of Environmental Conservation as 94-3. The national inventory prepared by the U.S. Army Corps of Engineers during Phase I Non-Federal Dam Investigations identifies this impoundment as VT00323. The dam is owned by the town of Hartford, Vermont.

b. Physical Characteristics

Type:	Earthen fill
Length:	390 feet
Height:	15 feet to downstream roadway (34 feet to downstream outlet)
Top Width:	Varies between 3 and 6 feet
Side Slope:	Upstream face from 2H:1V to 2.5H:1V Downstream face from 1.5H:1V to 2H:1V

c. Outlets

Principal Outlet: About 100 feet in length 8-inch diameter cast iron pipe. Maximum outlet capacity with pool at top of dam is about 5 cfs.

Spillway: Trapezoidal earth cut spillway on the right abutment with a 6 foot bottom width at elevation 1097.5 feet NGVD and a 12 foot top width. Maximum spillway discharge with the pool at top of dam is estimated at 75 cfs.

d. Impoundment Behind Dam

Surface Area: 2.5 acres at spillway crest
3.0 acres at top of dam.

Height of Dam (to Downstream Outlet):
31.8 feet at spillway crest
34 feet at top of dam

Estimated Storage Volume (from State Inventory):
20 acre-feet at spillway crest
25 acre-feet at top of dam

e. Dam Site Elevations

Top of Dam:	1099.8 feet NGVD
Spillway Crest:	1097.5 feet NGVD
Invert Outlet:	1066.0 feet NGVD
Downstream Streambed:	1065.7 feet NGVD

f. Watershed Area

Size: 68 acres (0.106 square mile)
Type: Woodland with steep slopes and minimal development

4. METHOD OF ANALYSIS

a. Introduction. This section discusses the methods and assumptions used in the dam-break analysis. Two types of dam failures were considered in this study: "sunny-day" and "storm-day" failures.

A sunny-day failure is typically a result of piping failure. Piping is internal erosion of the embankment through displacement of fines by seepage. The erosion creates voids in the embankment and, therefore, could lead to breach and eventual collapse of the dam.

A storm-day failure is associated with significant inflow into the impoundment. As a result of both inadequate spillway and reservoir storage capacities, overtopping of the embankment occurs. This overtopping erodes the embankment and, therefore, could cause breach and failure of the dam.

b. Hydrology. To accomplish dam-break analyses, inflow hydrographs for the reservoir resulting from a 100-year storm and four fractions (1, 3/4, 1/2, 1/4) of the PMF were developed. Data necessary for generating the hydrographs include rainfall data and watershed characteristics.

Rainfall data for the 100-year storm was obtained from National Weather Service Technical Paper 40, "Rainfall Frequency Atlas of the United States." To develop a worst case distribution, the 24-hour duration rainfall data were critically arrayed so that the peak occurred at the twelfth hour preceded by the second largest rainfall increment and followed by the third largest. Total 24-hour, 100-year precipitation for this location is 5.5 inches.

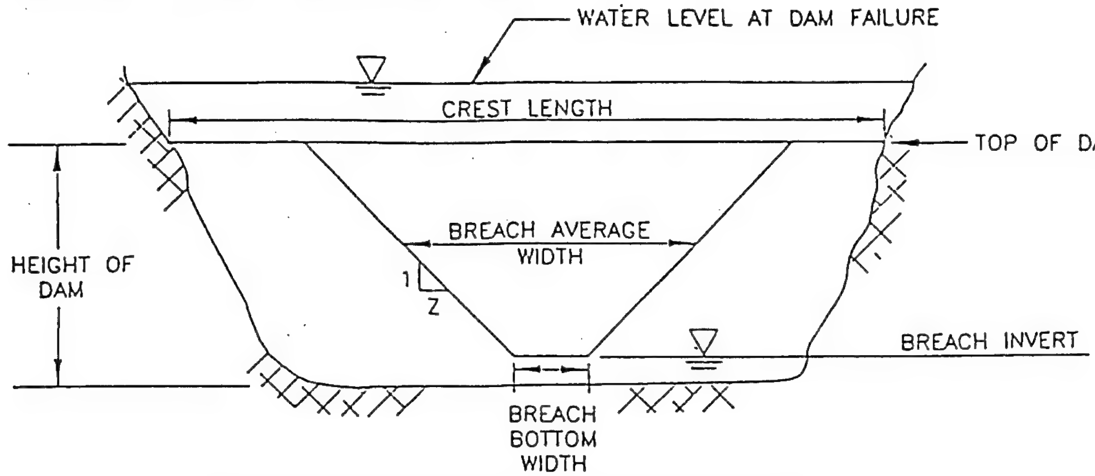
The PMF was developed from the probable maximum precipitation (PMP). Hydrometeorological Reports 51 and 52 provided the rainfall data and guidelines for applying it and the Corps computer program HMR52 was used to develop the PMP for this watershed. The peak 24-hour rainfall was taken from the derived 72-hour PMP and critically arrayed similarly to the 100-year rainfall. The resulting 24-hour PMP is 27.7 inches, with a peak 15-minute increment of 7.1 inches.

Runoff from these rainfall events was developed using the Corps computer model HEC-1. Inflow hydrographs were developed using the SCS method which accounts for soil permeability and rainfall losses with a single parameter, runoff curve number. For this heavily wooded watershed underlain, primarily with till, a curve number of 50 was adopted (table 1). The lag time for the watershed based on overland slope and flow length, was computed to be one hour.

c. Reservoir Routing. The inflow hydrographs were routed through the reservoir to obtain outflow flood hydrographs based on the storage and outlet capacities of the dam. Initial reservoir routing was performed using HEC-1 assuming the dam does not breach. Modified Puls (storage) routing was used to determine which inflows (100-year and fractions of the PMF) cause overtopping, which in turn might lead to breach. This inflow was then adopted for the storm-day scenario. The storm-day and sunny-day dam-breaks were analyzed using the National Weather Service DAMBRK model, which solves the complete unsteady flow equations.

d. Spillway Hydraulic Capacity. A rating curve for Upper Hurricane Reservoir was developed based on the geometry of the spillway and the dam. Flow through the 8-inch cast iron pipe was determined to be negligible. Flows over the spillway and over the top of dam were determined using the weir equation. This outflow rating curve was used in routing the inflow hydrographs through the reservoir with the HEC-1 model.

e. Breach Discharge Hydrograph. The discharge hydrograph of a breach is a function of the inflow hydrograph and breach parameters of a hypothetical dam failure. The sketch below illustrates the various dam breach parameters for a typical earth-fill dam. Total outflow is a combination of flows through the breach and the spillway. As the breach in the dam develops, so does the breach discharge.



DEFINITION SKETCH OF BREACH PARAMETERS

f. Assumed breach Parameters

Assumed Piping (Sunny-Day) Failure Condition

Initial Pool Level: Spillway crest 1097.5 feet NGVD

Dam Failure Level: El. 1097.5 feet NGVD

Breach Invert: Pool invert 1085.6 feet NGVD
(measured 8/15/94 during dry pool)

Breach Bottom Width: 50 feet with side slopes 1V:1H

Time to Complete Formation of Breach: 0.5 hour

Downstream Reach Roughness (Manning's "n" Values):
Channel = 0.035 to 0.055
Overbank = 0.055 to 0.10

Embankment Geometry:
Height of Dam = 14.2 feet
Crest Length = 390 feet

Assumed Overtopping (Storm-Day) Failure Condition

Initial Pool Level: Spillway crest 1097.5 feet NGVD

Dam Failure Level: El. 1099.8 feet NGVD

Breach Invert: Pool invert 1085.6 feet NGVD
(measured 8/15/94 during dry pool)

Breach Bottom Width: 70 feet with side slopes 1V:1H

Time to Complete Formation of Breach: 0.5 hour

Downstream Reach Roughness (Manning's "n" Values):
Channel = 0.035 to 0.055
Overbank = 0.055 to 0.10

Embankment Geometry:
Height of Dam = 14.2 feet
Crest Length = 390 feet

g. Downstream Channel Routing. A downstream channel routing analysis allows the breach discharge and hydrograph to be characterized at points of interest below the dam. A breach hydrograph is attenuated and stored through a downstream channel and flood plain in a manner similar to that by which an inflow hydrograph is routed through a reservoir. The degree to which this breach discharge is attenuated is a function of the downstream valley storage capacity and valley roughness characteristics.

The dynamic wave method of channel routing is used in the NWS DAMBRK computer program to route the flood wave downstream. This is a hydraulic routing method that solves the complete unsteady flow equations through a given reach. Results of this method indicate attenuation of the flood wave, resulting flood stages, and the time it takes for the wave to reach the section.

Downstream valley storage was determined by obtaining reach cross sections from field surveys and USGS topographic quadrangles. Manning's "n" values were assigned to the channel and overbanks on the basis of field observations.

The downstream channel routing procedure is based on the assumption that flow structures below the dam (i.e., Simonds Reservoir dam and the Route 5, Interstate 91, and River Road culverts) do not become blocked with debris. The hydraulic

rating data for these structures assumes full hydraulic capacity. If structures become blocked with debris, the peak water surface elevation behind them could increase to stages higher than estimated.

In addition, all flow structures were assumed not to fail in the dam-break computer model in order to estimate the maximum water levels expected. However, due to the increased flood stages and velocities associated with a dam-break, failure of any or all of these structures is possible. This study does not attempt to determine if any downstream structures will fail during a dam-break at Upper Hurricane Reservoir.

In order for the NWS DAMBRK model to mathematically converge on initial (antecedent) channel conditions, a minimum amount of flow is required. The initial channel flow for both cases was assumed to be 100 cfs. This was the minimum flow for which the program converged and results became stable. This is primarily due to the extremely steep nature of the downstream reach which results in critical or supercritical flow for most of the reach. Although 100 cfs is higher than observed flows, it results in a minimal depth (less than 2 feet) of initial flow in the channel. In addition to this initial flow, the storm-day routing included an inflow equivalent to the 1/2 PMF. The 1/2 PMF discharge hydrograph was routed through Upper Hurricane Reservoir and the dam was assumed to fail when the pool reached the top of the dam. Due to the relatively small nature of the drainage areas involved, 1/2 PMF discharges were also developed for uncontrolled drainage areas (Lower Hurricane Reservoir and Kilburn Brook). These discharges were input to the DAMBRK model as lateral inflows at the confluence of Upper and Lower Hurricane Reservoir exit channels and at the confluence with Kilburn Brook.

h. Project Mapping. Project mapping was obtained by enlarging the USGS, Quechee, VT and Hanover, NH and VT Quadrangles, 7.5 minute series, photorevised 1980. Locations of structures within the inundation limits were verified through field survey and site reconnaissance. The original scale of 1:24,000 was enlarged to 1:6,000.

i. Vertical Control. Vertical control for this investigation was obtained by using a standard USGS disk set in the west headwall of a 4 foot by 4 foot concrete box culvert 100 feet south along Route 5 from the Maple Row Farm, elevation 573.187 feet NGVD. Additional control was taken from a U.S. Supreme Court Boundary disk set in a granite monument 0.3 foot above ground. It is 18 feet west of the railroad track between the lanes of Interstate 89, under the bridge and is stamped 21A, elevation 368.76 feet NGVD.

5. RESULTS OF ANALYSIS

a. Inflow Hydrograph. As presented in table 1, the peak inflow resulting from a 100-year storm event was 33 cfs and a 1/2 PMF resulted in a peak inflow of 193 cfs. Plate 3 shows that the 100-year storm inflow hydrograph peaks at 14 hours into a 24-hour storm. Plate 4 shows that the 1/2 PMF peaks at 13.25 hours into a 24-hour storm. These hydrographs were developed using the HEC-1 computer program.

b. Reservoir Storage Capacity. The maximum storage capacity at the top of dam is approximately 25 acre-feet. As determined from the 100-year inflow hydrograph analysis, 23 acre-feet is stored behind the dam, so that the resulting maximum stage under this storm event is 1098.8 feet NGVD. The 1/4 PMF is the only fraction of the PMF analyzed which does not overtop the dam. Maximum stage is 1099.5, about 0.3 foot below the low point in the dam, and resulting storage is 25 acre feet.

c. Spillway Hydraulic Capacity. Maximum spillway hydraulic capacity at the top of dam is approximately 70 cfs, which excludes any flow through the 8-inch CIP low level outlet. Upper Hurricane Reservoir appears to have sufficient spillway capacity and adequate storage to route and pass the 100-year and 1/4 PMF storm events without overtopping the dam. Peak discharges without dam failure for these events are 26 and 51 cfs, respectively.

d. Breach Discharge Hydrograph. Tables 2 and 3 summarize the peak discharge and downstream channel routing results assuming a sunny-day and storm-day failure, respectively.

Sunny-day failure of Upper Hurricane Reservoir resulted in a peak breach discharge of approximately 762 cfs. The water surface was at elevation 1097.5 feet NGVD when failure began, and the breach was modelled to develop fully within 30 minutes. Plates 10 and 11 show the sunny-day breach discharge over time and distance downstream.

Storm-day failure results in a peak breach discharge of 940 cfs with the 1/2 PMF as the inflow. Failure begins once the water reaches the top of dam elevation 1099.8 feet NGVD, and the breach is assumed to develop fully within 30 minutes. Plates 12 and 13 show the storm-day breach discharge over distance and time. Plates 10 through 13 are graphical outputs from the Boss DAMBRK computer model.

TABLE 1

Upper Hurricane Reservoir
Hartford, Vermont

100-Year and PMF Inflow Reservoir Routing Summary

Flood Frequency	Peak Inflow (cfs)	Peak Outflow (cfs)	Maximum Pool Level (ft NGVD)	Available Freeboard (feet)
100-year	33	26	1098.8	1.0
1/4 PMF	67	51	1099.5	0.3
1/2 PMF	193	193	1100.3	Overtopped
3/4 PMF	337	337	1100.5	Overtopped
Full PMF	487	487	1100.6	Overtopped

Drainage area of 0.1 square miles

Discharge computed using HEC-1; non-failure assumed

Freeboard measured from maximum pool level to top of dam (assumed 1100)

TABLE 2

Upper Hurricane Reservoir
Hartford, Vermont

Downstream Channel Routing Results
Sunny-Day Failure

Downstream Location	Peak Discharge (cfs)	Elevation (ft NGVD)	Above Streambed (feet)	Time to Peak (hours)
Upper Hurricane Reservoir (0.0 mi.)	762	1097.5	11.9	0.5
U/S Confluence of Upper and Lower (0.42 mi.)	738	883.7	3.7	1.0
Simonds Reservoir (1.1 mi.)	516	709.0	5.1	1.1
US Route 5 (1.42 mi.)	512	605.6	4.8	1.1
U/S Confluence of Kilburn Brook (2.09 mi.)	459	463.3	3.3	1.2
River Road (2.54 mi.)	437	382.4	11.2	1.3
Central Vermont Railroad (2.60 mi.)	435	362.7	4.7	1.3

Time to peak measured from start of breach

TABLE 3

Upper Hurricane Reservoir
Hartford, Vermont

Downstream Channel Routing Results
Storm-Day Failure

Downstream Location	Peak Discharge (cfs)	Elevation (ft NGVD)	Above Streambed (feet)	Time to Peak (hours)
Upper Hurricane Reservoir (0.0 mi.)	940	1099.8	14.2	0.5
U/S Confluence of Upper and Lower (0.42 mi.)	873	883.9	3.9	0.9
Simonds Reservoir (1.1 mi.)	644	710.4	6.5	1.1
US Route 5 (1.42 mi.)	642	606.1	5.3	1.1
U/S Confluence of Kilburn Brook (2.09 mi.)	600	463.6	3.6	1.1
River Road (2.54 mi.)	1094	383.1	11.9	1.2
Central Vermont Railroad (2.60 mi.)	1093	364.9	6.9	1.2

Time to peak measured from start of breach

6. DOWNSTREAM CHANNEL ROUTING

Plates 7 through 9 show peak water surface profiles resulting from both the sunny and storm-day dam failure scenarios.

a. Sunny-Day Results. The sunny-day peak breach discharge of 762 cfs had little attenuation as it approached the confluence with Lower Hurricane Reservoir outlet stream.

Peak discharge at Simonds Reservoir (1.1 miles downstream) was 516 cfs. Corresponding maximum water level at Simonds Reservoir dam was 709.0 feet NGVD, about one foot over the top of the dam. Although this structure is in poor condition, it was not assumed to fail. If Simonds Reservoir were to fail, the resulting increase in discharge should be minimal since the pool only stores an estimated 3 acre-feet at the top of dam.

At U.S Route 5 (1.42 miles downstream), the peak discharge was 512 cfs, barely attenuated due to the steep slope of the river channel. Corresponding peak stage is computed by the model to be 605.6 feet NGVD, or six feet below the top of the roadway. However, based on engineering judgement, it seems unlikely that a 4.5-foot diameter culvert can pass this flow with only a minimal surcharge. In the likelihood that the roadway is overtopped, the roadway crossing would act like a broad crested weir with a capacity to discharge over 650 cfs when the upstream water surface reaches 613.0 feet NGVD. The lowest first floor sill in the area is at 613.04 feet NGVD, above both the computed dam-break flood peak and the expected stage resulting from road overtopping. However, just downstream of the road, a portion of the propane tank facility appears to be within the flooded area. The buildings at this facility are above the flood limits.

Peak discharge at River Road (2.54 miles downstream) is computed to be 437 cfs, with a resulting estimated stage of 382.4 feet NGVD (1 foot above the top of road). The houses in this area are considerably higher than the roadway and do not appear to be flooded, however, River Road provides the only access to part of this area.

At the Central Vermont Railroad, 2.6 miles downstream, peak discharge is 435 cfs. Peak stage is computed to be 362.7, about 12 feet below the top of the railroad embankment. The house near the tracks is also well above the flood plain.

b. Storm-Day Results. The storm-day peak breach discharge of 940 cfs was attenuated to 873 cfs as it approached the confluence with Lower Hurricane Reservoir outlet stream. Inflow from the routed 1/2 PMF inflow at Lower Hurricane Reservoir (360 cfs) was added to the dam-break discharge.

Peak discharge at Simonds Reservoir (1.1 miles downstream) was 644 cfs. Corresponding maximum water level at Simonds Reservoir dam was 710.4 feet NGVD, about 2.4 feet over the top of the dam. Although this structure is in poor condition, it was not assumed to fail. As discussed previously, if Simonds Reservoir were to fail, the resulting increase in discharge should be minimal since the pool only stores about 3 acre-feet at the top of dam.

At U.S Route 5 (1.42 miles downstream), the peak discharge was 642 cfs, attenuated little due to the steep slope of the river channel. Corresponding peak stage is 606.1 feet NGVD, or 5.5 feet below the top of the roadway. As in the sunny-day scenario discussed above, calculations were made to estimate the expected peak water surface elevation. During overtopping, the roadway crossing acts like a broad crested weir with a capacity to discharge over 650 cfs when the upstream water surface reaches 613.0 feet NGVD. The lowest first floor sill in the area is at 613.04 feet NGVD, above both the computed dam-break flood peak and the expected stage resulting from road overtopping. However, just downstream of the road, a portion of the propane tank facility appears to be within the flooded area. The buildings at this facility are above the flood limits.

Peak discharge at River Road (2.54 miles downstream) is computed to be 1,094 cfs, with about 540 cfs coming from the half-square-mile uncontrolled drainage area of Kilburn Brook. Peak estimated stage of 383.4 feet NGVD is about two feet above the top of road. The houses in this area are well above the flood plain of the brook.

At the Central Vermont Railroad, 2.6 miles downstream, peak discharge is 1,093 cfs. Peak stage is computed to be 364.9 feet NGVD, about 10 feet below the top of the railroad embankment. The house near the tracks is also well above the flood plain.

7. INUNDATION MAPPING

The limits of inundation were computed by routing the breach discharge hydrograph through the downstream valley cross sections and delineating the resulting maximum stages on the base map. The base map used is based on a 20-foot contour interval 1:24,000 scale USGS quadrangle, and therefore, inundation limits shown on plates 5 and 6 are only approximate. Although any structures shown within these limits were assumed to be inundated, certain structures may be excluded as a result of local conditions and elevations.

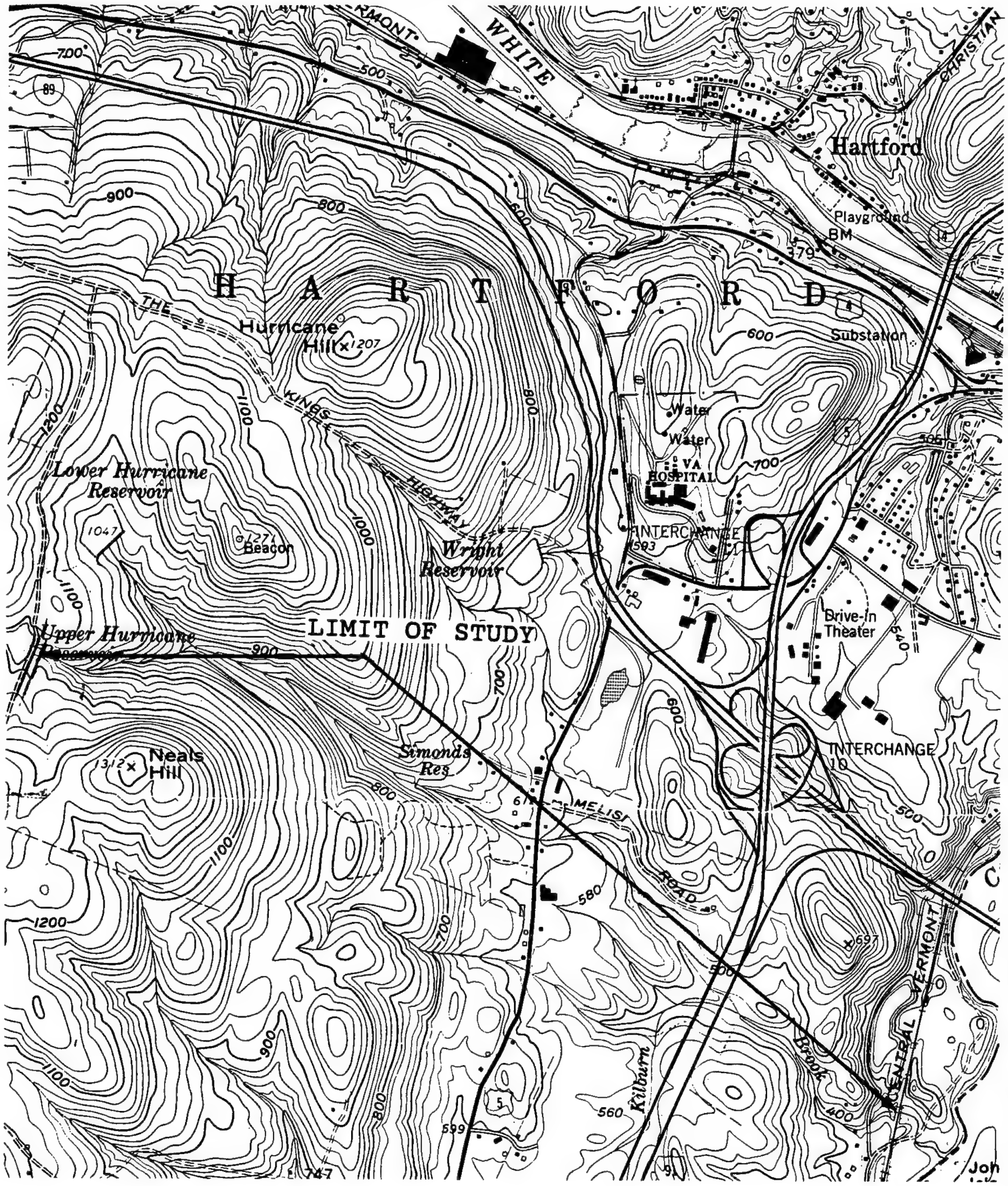
8. SIZE CLASSIFICATION

Upper Hurricane Reservoir is about 15 feet high from the top of the dirt roadway at its downstream toe. However, if the road is part of the dam structure, the height could be as much as 34 feet. The maximum available storage with the pool at the top of the dam is 25 acre-feet. According to Article 2.1.1 of the Recommended Guidelines for Safety Inspection of Dams, the dam size is "SMALL."

9. HAZARD CLASSIFICATION

On the basis of its potential to cause downstream damage, Upper Hurricane Reservoir is given a Class 2, "SIGNIFICANT" hazard classification; refer to the Downstream Hazard Classification of Dams on page 2 of this report.

Damage resulting from both the sunny and storm-day failures could include streambank erosion and overtopping of three roadways (Kings Highway, Route 5, and River Road) as well as one downstream dam (Simonds Reservoir). Although the first floor elevations of two habitable structures are slightly above the computed peak flood elevations, ground elevations at these structures are within the flood limits. Debris blockages or other factors could increase flood elevations at these structures, consequently they should be considered potentially at risk. Additionally, a portion of the propane facility is also within the flood limits. Numerous size propane tanks were observed to be stored within 10 or 20 feet of the stream channel downstream of U.S. Route 5.



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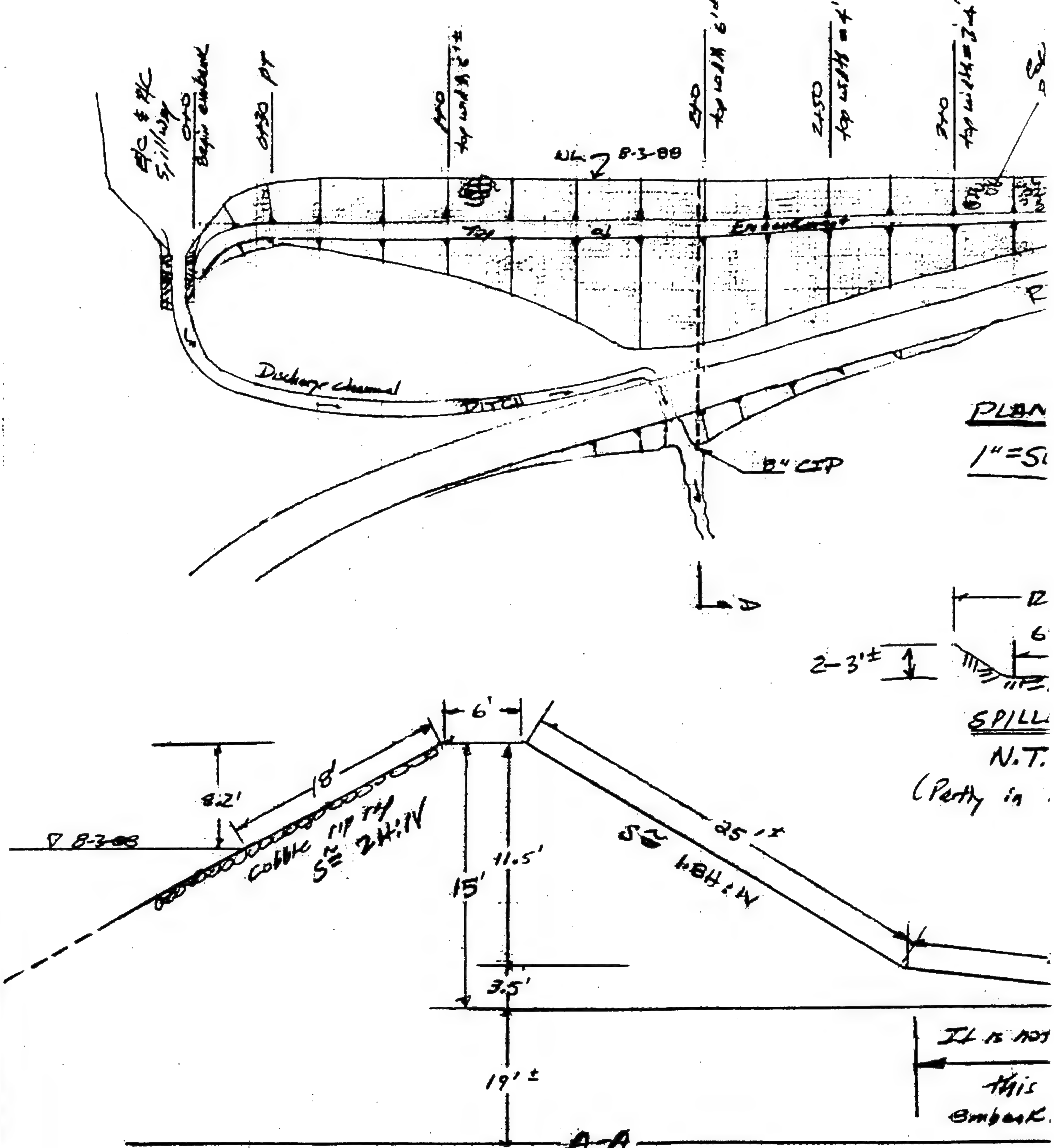
Scale in Feet

Upper Hurricane Reservoir
Hartford, Vermont

DAM-BREAK FLOOD ANALYSIS

STUDY AREA

PLATE 1



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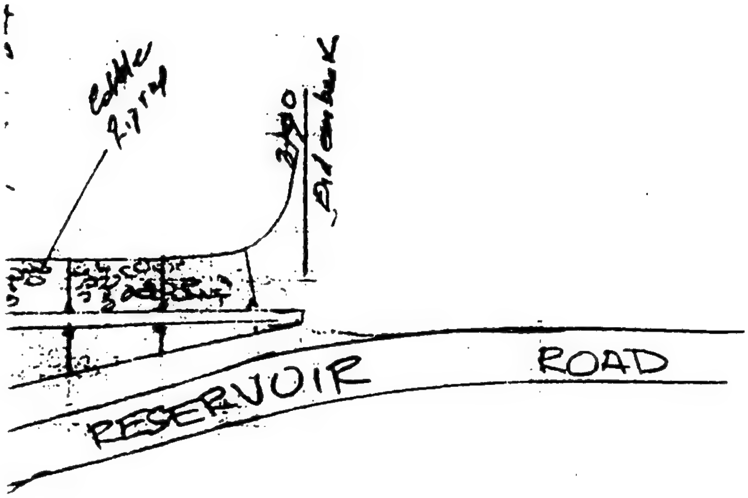
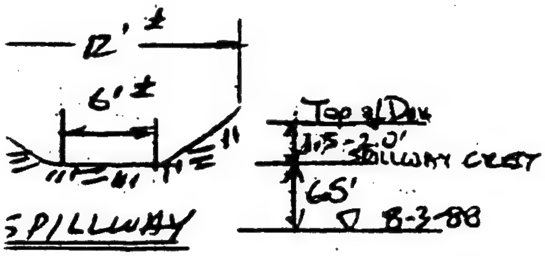


L = 390'±
Top width = 3'-6'

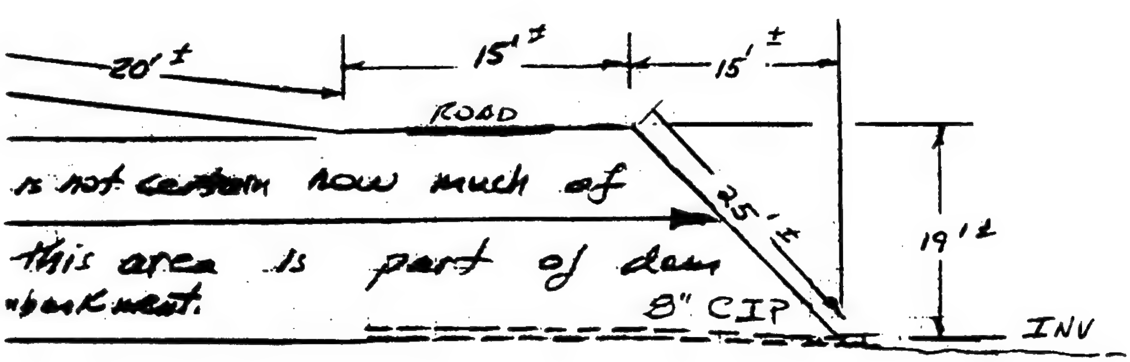
PLAN
1" = 50'

UPPER HURRICANE
RESERVOIR DAM

Hartford
DEC # 94-3



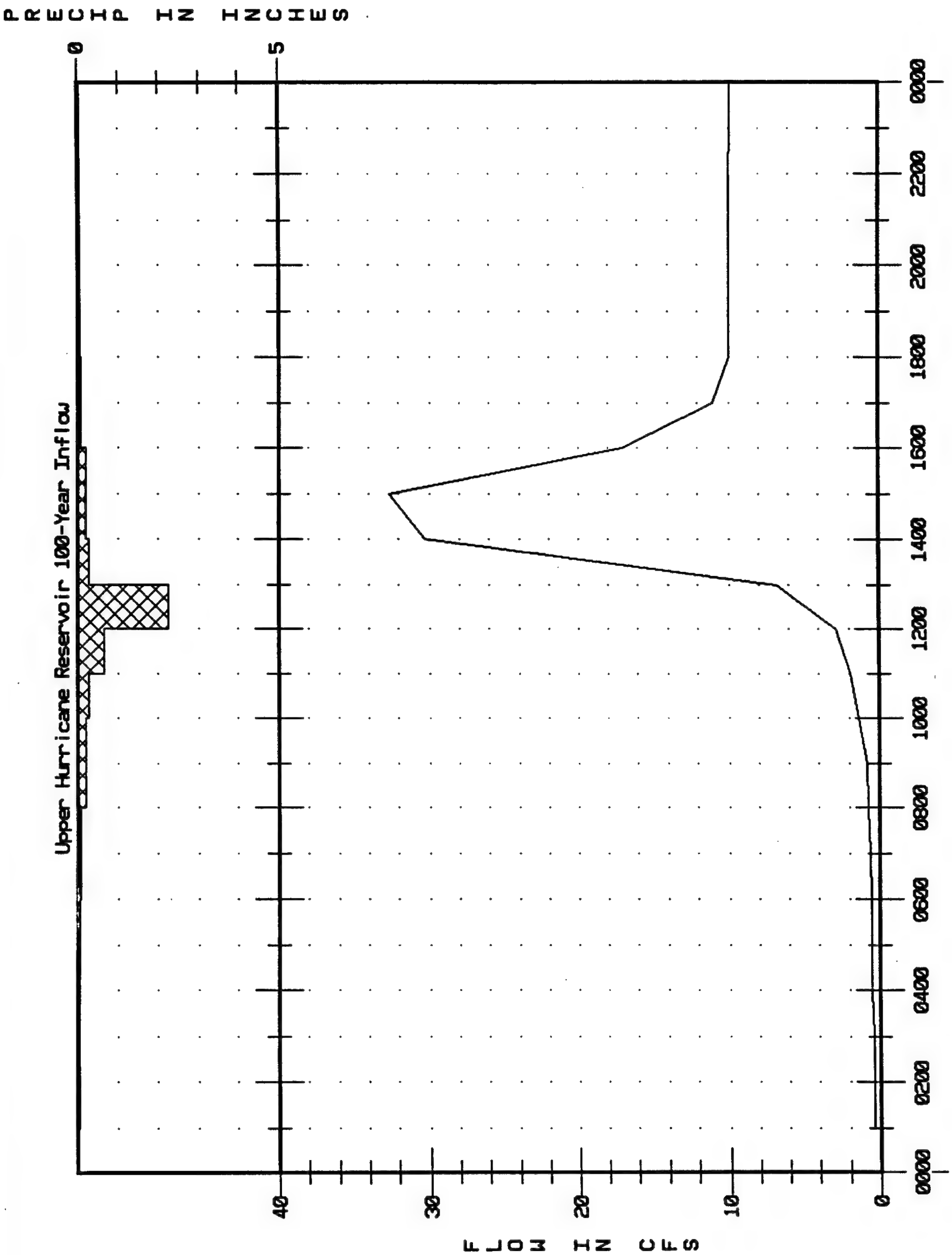
SPILLWAY
N.T.S
, in rock)



Drawn 8-9-88
APB

Revised 5/18/94
By U.S. Army Corps Survey

PLATE 2



Upper Hurricane Reservoir 100-Year Inflow
PRECIP IN INCHES
0
5
FLOW IN CFS
40
30
20
10
0
0000
0200
0400
0600
0800
1000
1200
1400
1600
1800
2000
2200
0000

PLATE 3

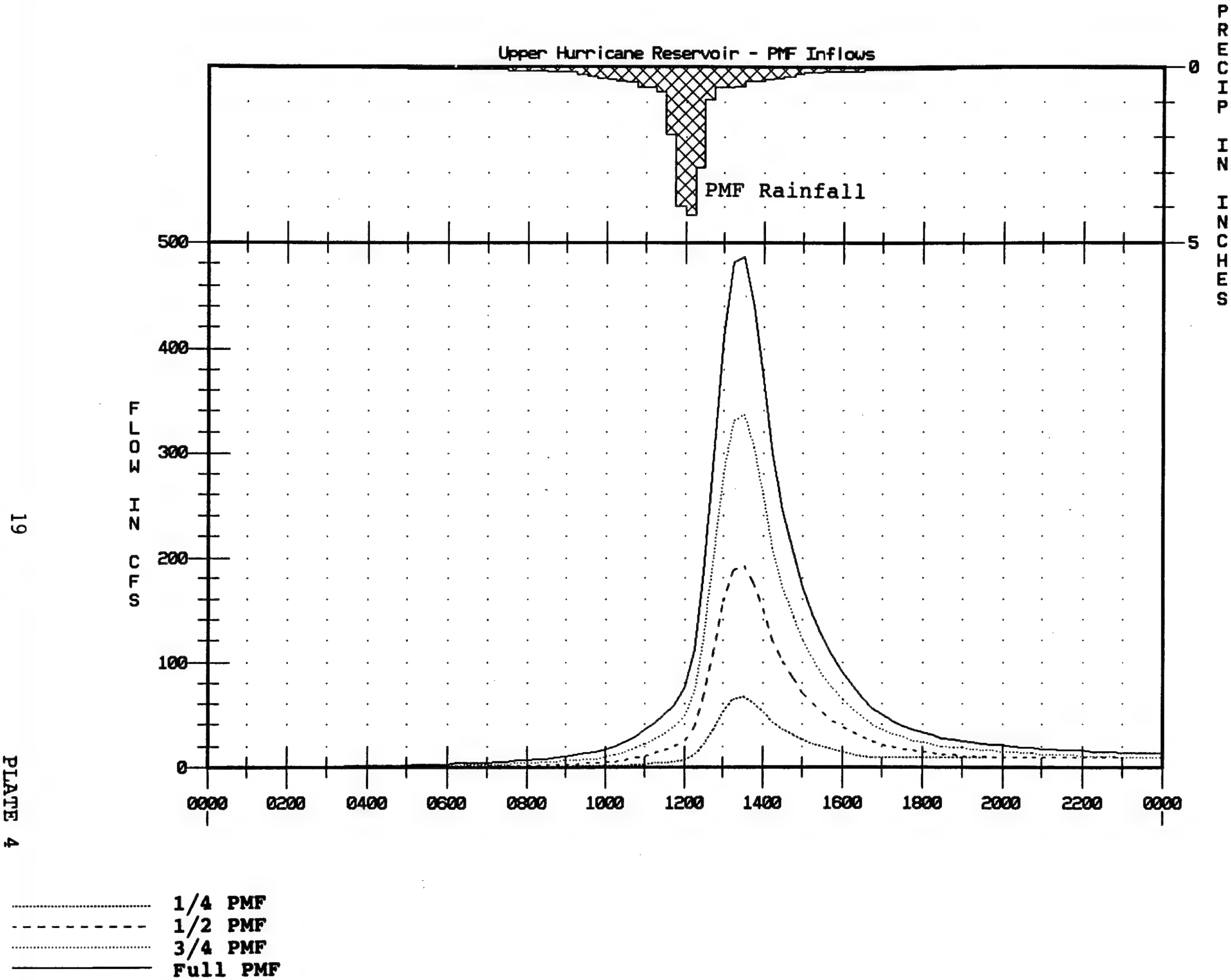
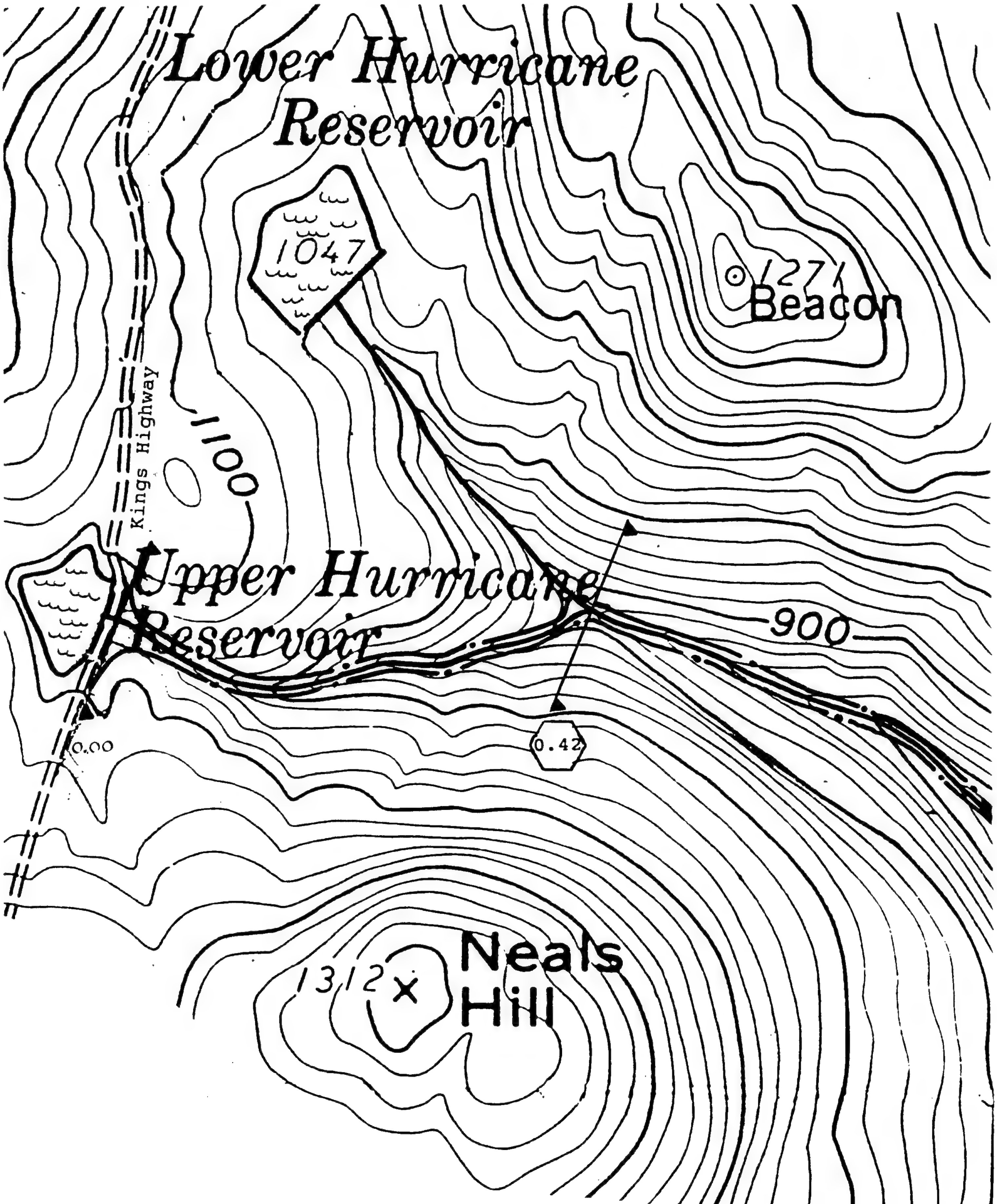
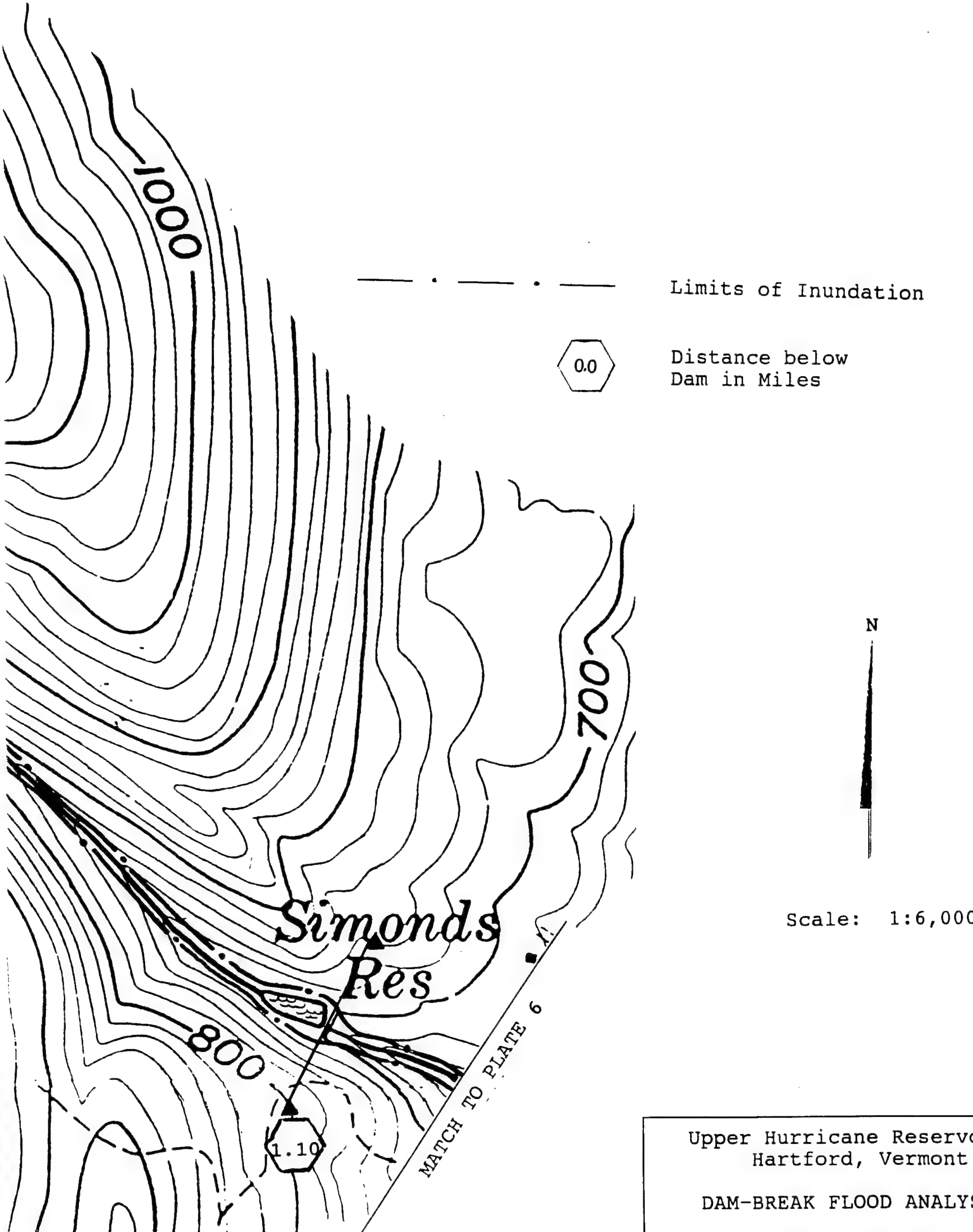

Upper Hurricane Reservoir - PMF Inflows
PMF Rainfall
PRECIP IN INCHES
0
5
FLOW IN CFS
500
400
300
200
100
0
0000
0200
0400
0600
0800
1000
1200
1400
1600
1800
2000
2200
0000
1/4 PMF
1/2 PMF
3/4 PMF
Full PMF

PLATE 4

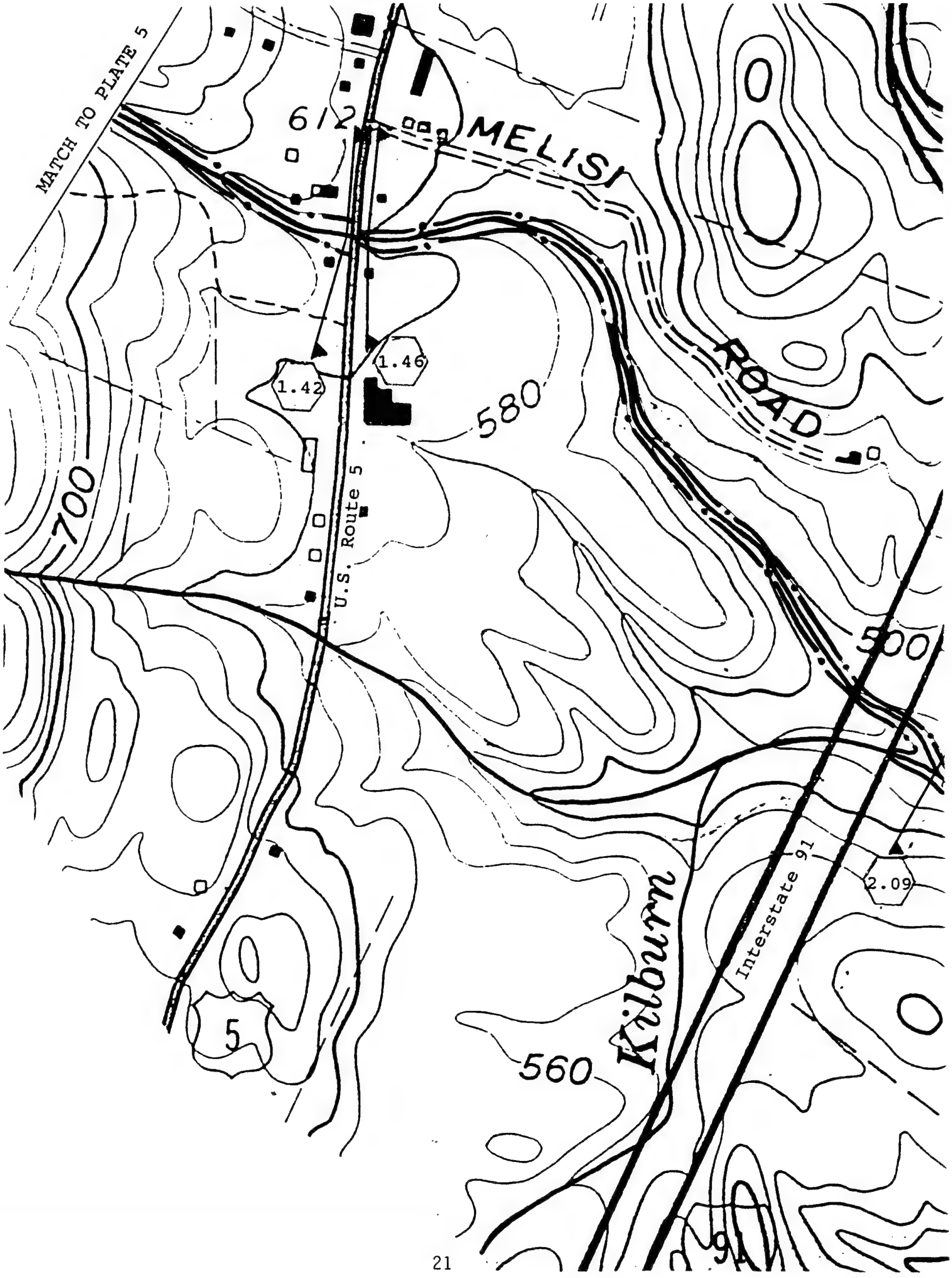

Lower Hurricane Reservoir
1047
1271
Beacon
1100
Kings Highway
Upper Hurricane Reservoir
900
0.00
0.42
Neals Hill
1312



Upper Hurricane Reservoir
Hartford, Vermont

DAM-BREAK FLOOD ANALYSIS

INUNDATION MAP
PLATE 5


MATCH TO PLATE 5
612
MELISI
ROAD
1.46
1.42
580
700
U.S. Route 5
500
2.09
Interstate 91
Kilburn
560
5
91

Limits of Inundation

0.0 Distance below Dam in Miles

N

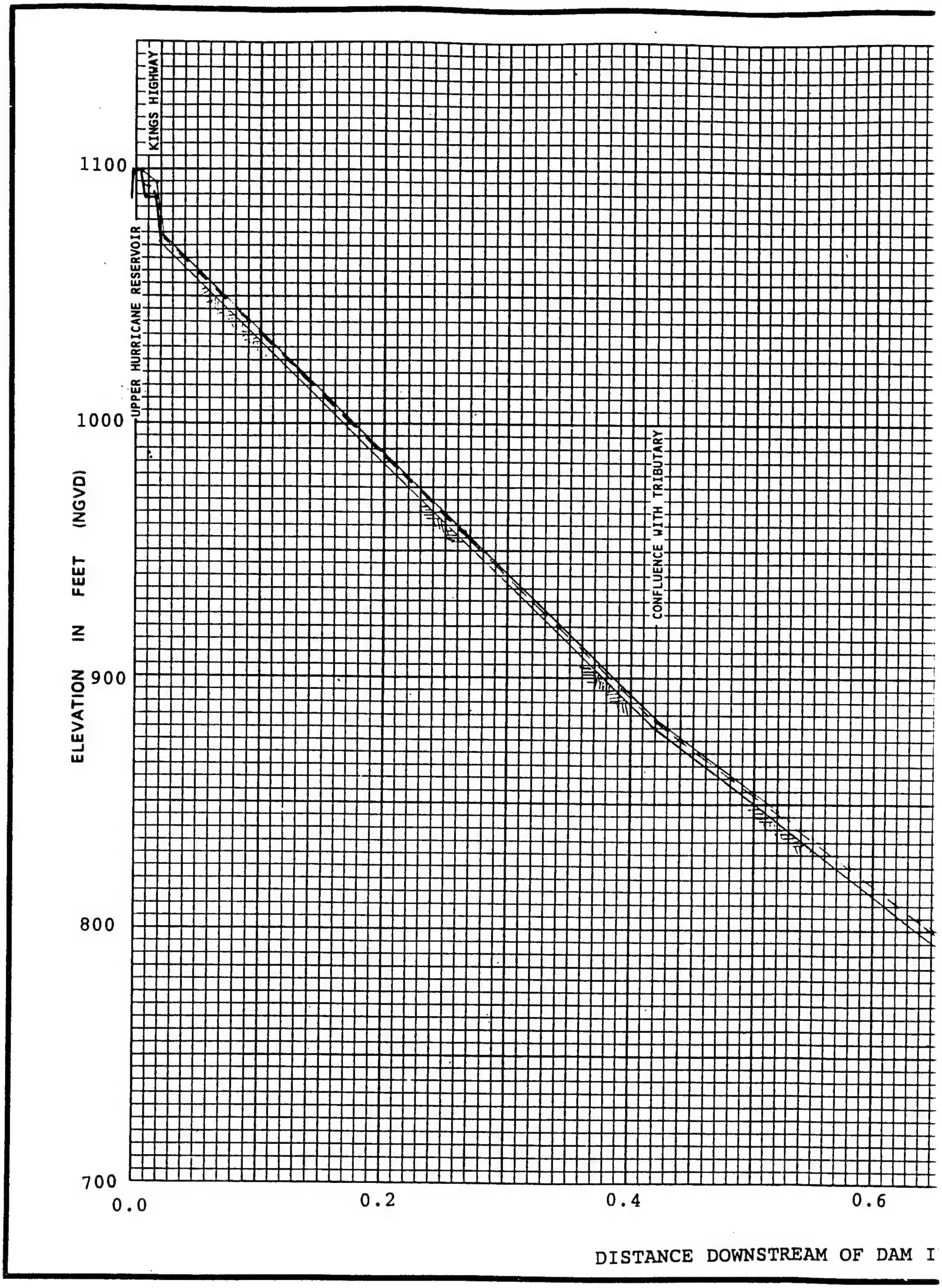
Scale: 1:6,000

Upper Hurricane Reservoir
Hartford, Vermont

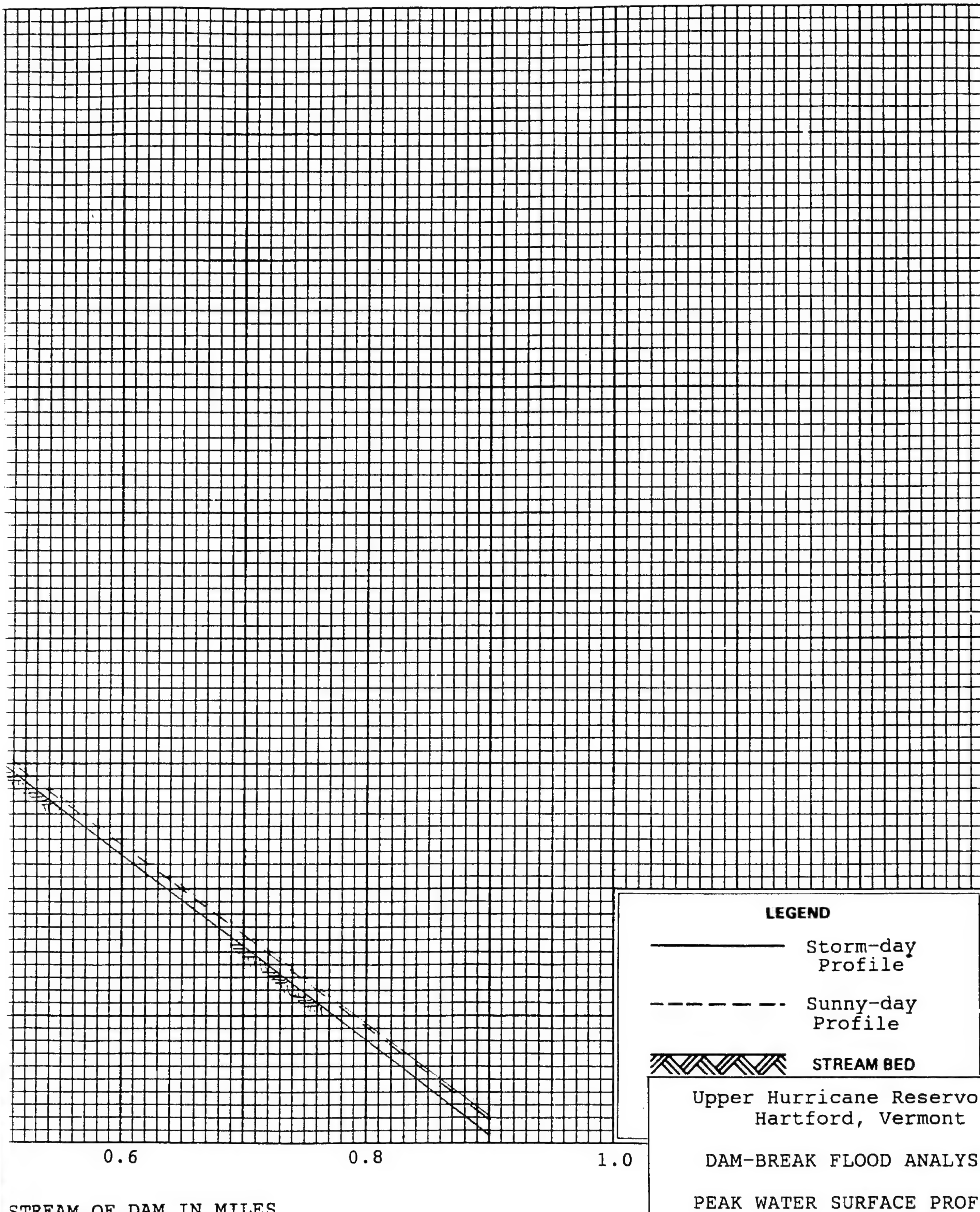
DAM-BREAK FLOOD ANALYSIS

INUNDATION MAP

PLATE 6



KINGS HIGHWAY
UPPER HURRICANE RESERVOIR
CONFLUENCE WITH TRIBUTARY
ELEVATION IN FEET (NGVD)
1100
1000
900
800
700
0.0
0.2
0.4
0.6
DISTANCE DOWNSTREAM OF DAM I

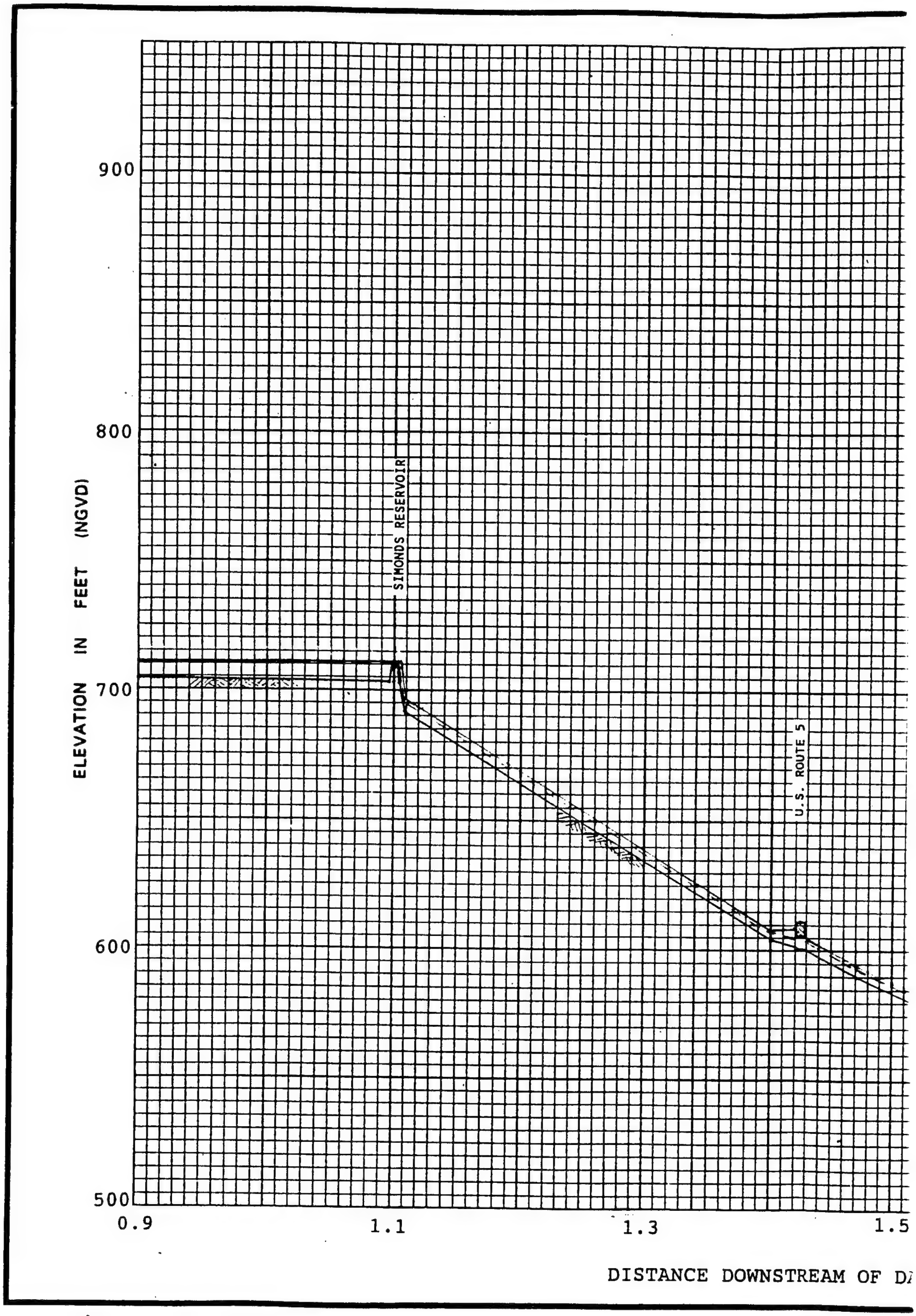


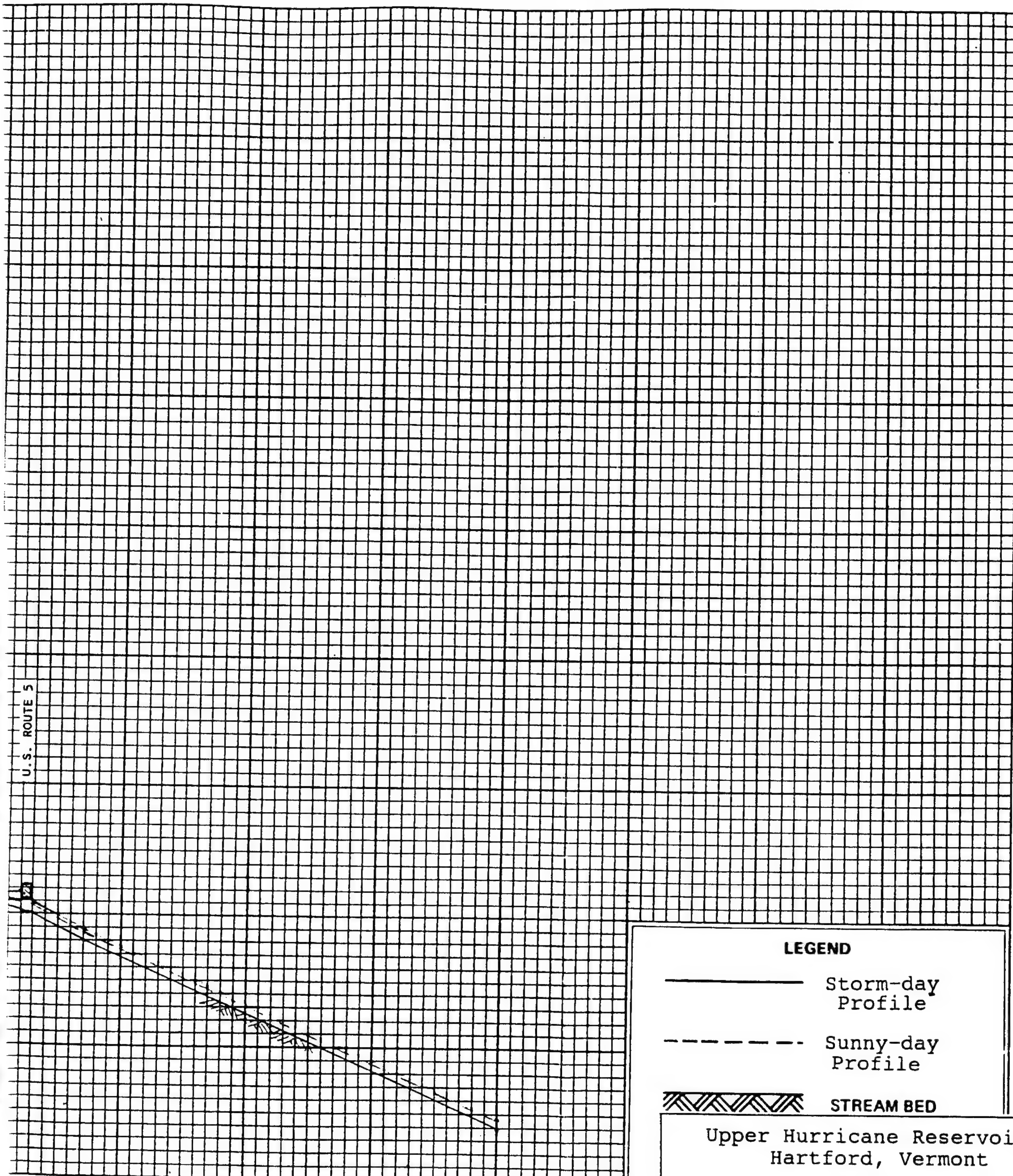
Upper Hurricane Reservoir
Hartford, Vermont

DAM-BREAK FLOOD ANALYSIS

PEAK WATER SURFACE PROFILE

PLATE 7

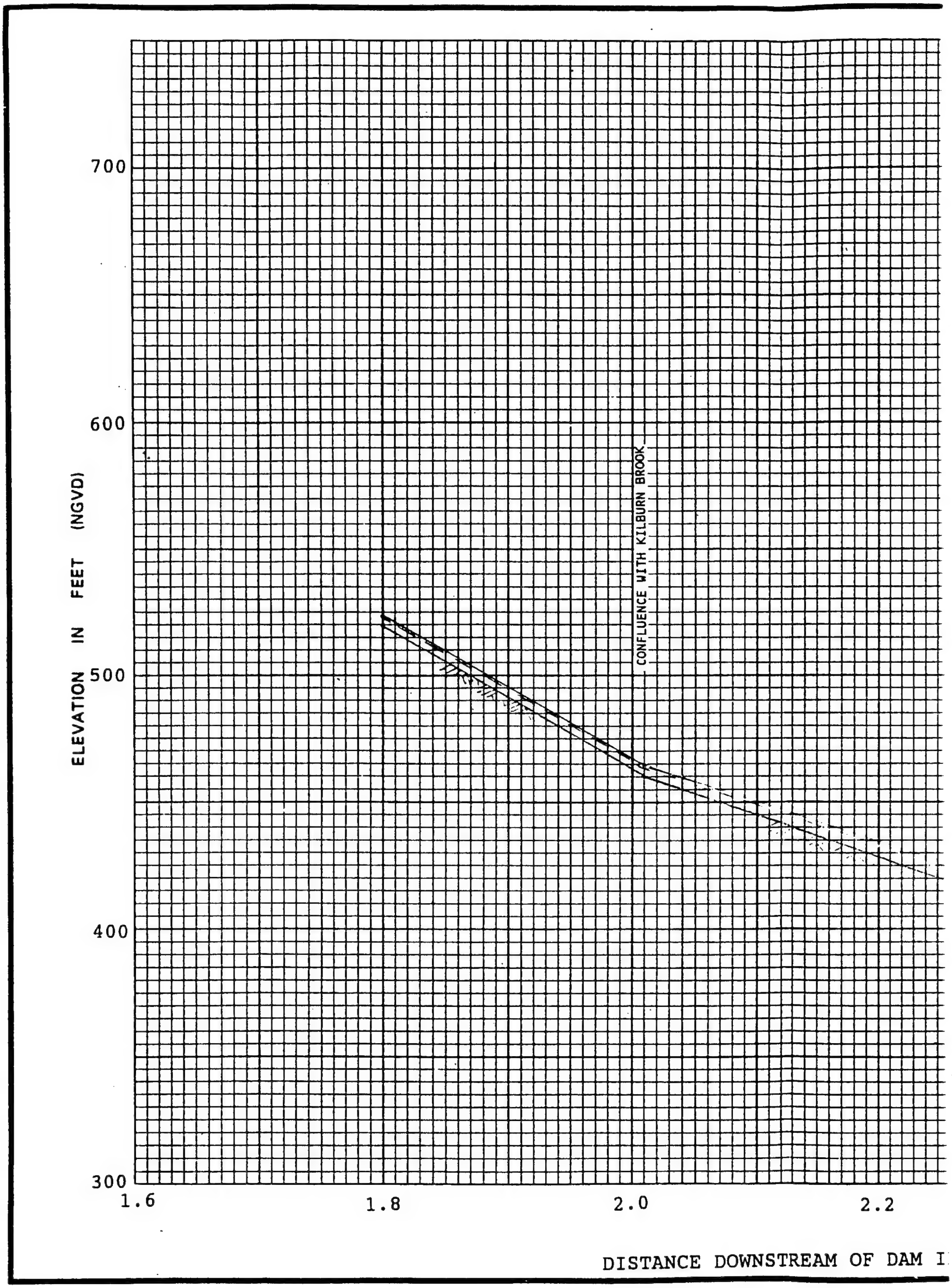

900
800
700
600
500
ELEVATION IN FEET (NGVD)
SIMONDS RESERVOIR
U.S. ROUTE 5
0.9
1.1
1.3
1.5
DISTANCE DOWNSTREAM OF D

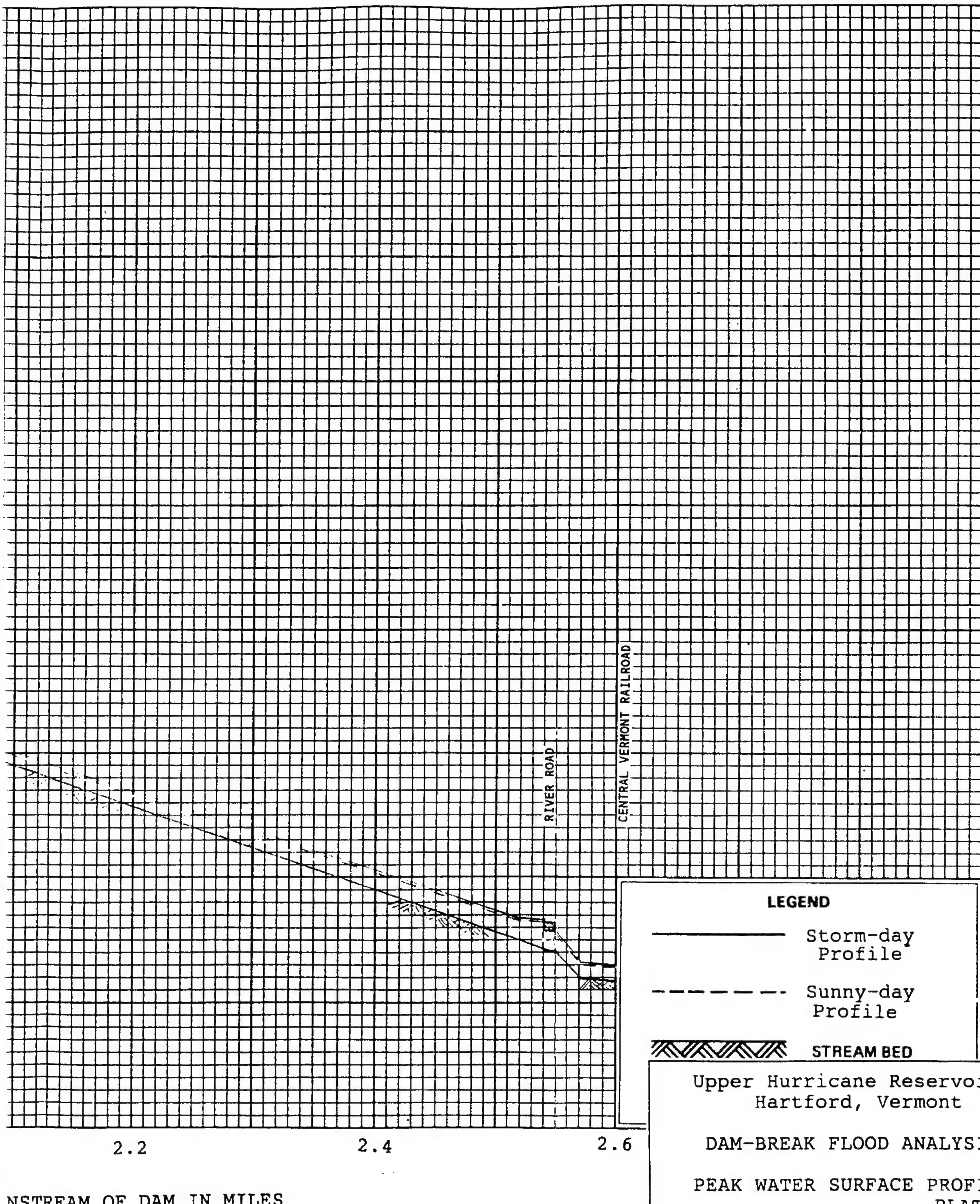


Upper Hurricane Reservoir
Hartford, Vermont

DAM-BREAK FLOOD ANALYSIS

PEAK WATER SURFACE PROFILE
PLATE 8


700
600
500
400
300
ELEVATION IN FEET (NGVD)
CONFLUENCE WITH KILBURN BROOK
1.6
1.8
2.0
2.2
DISTANCE DOWNSTREAM OF DAM I



Upper Hurricane Reservoir
Hartford, Vermont

DAM-BREAK FLOOD ANALYSIS

PEAK WATER SURFACE PROFILE

PLATE 9

SUNNY-DAY FAILURE

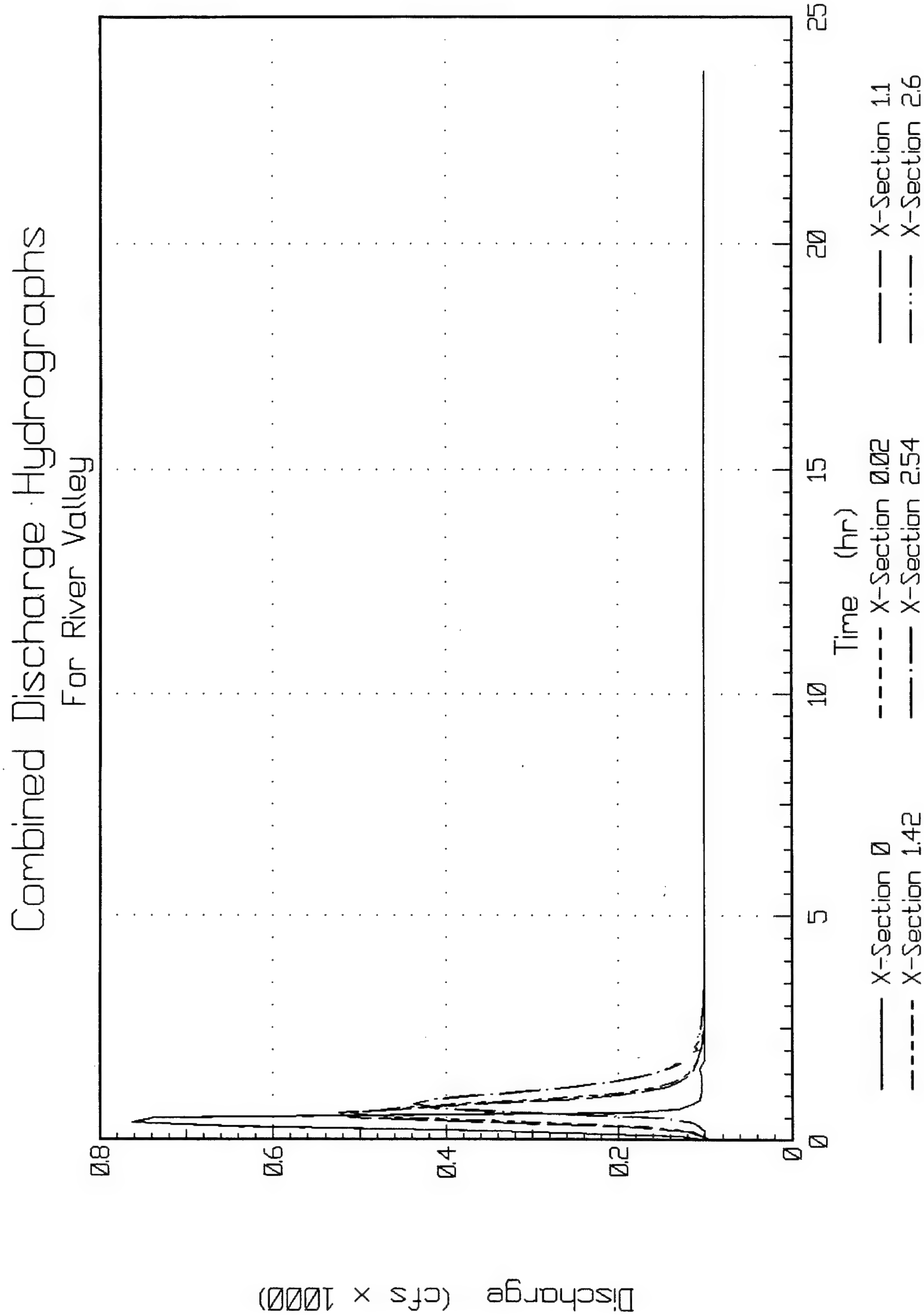
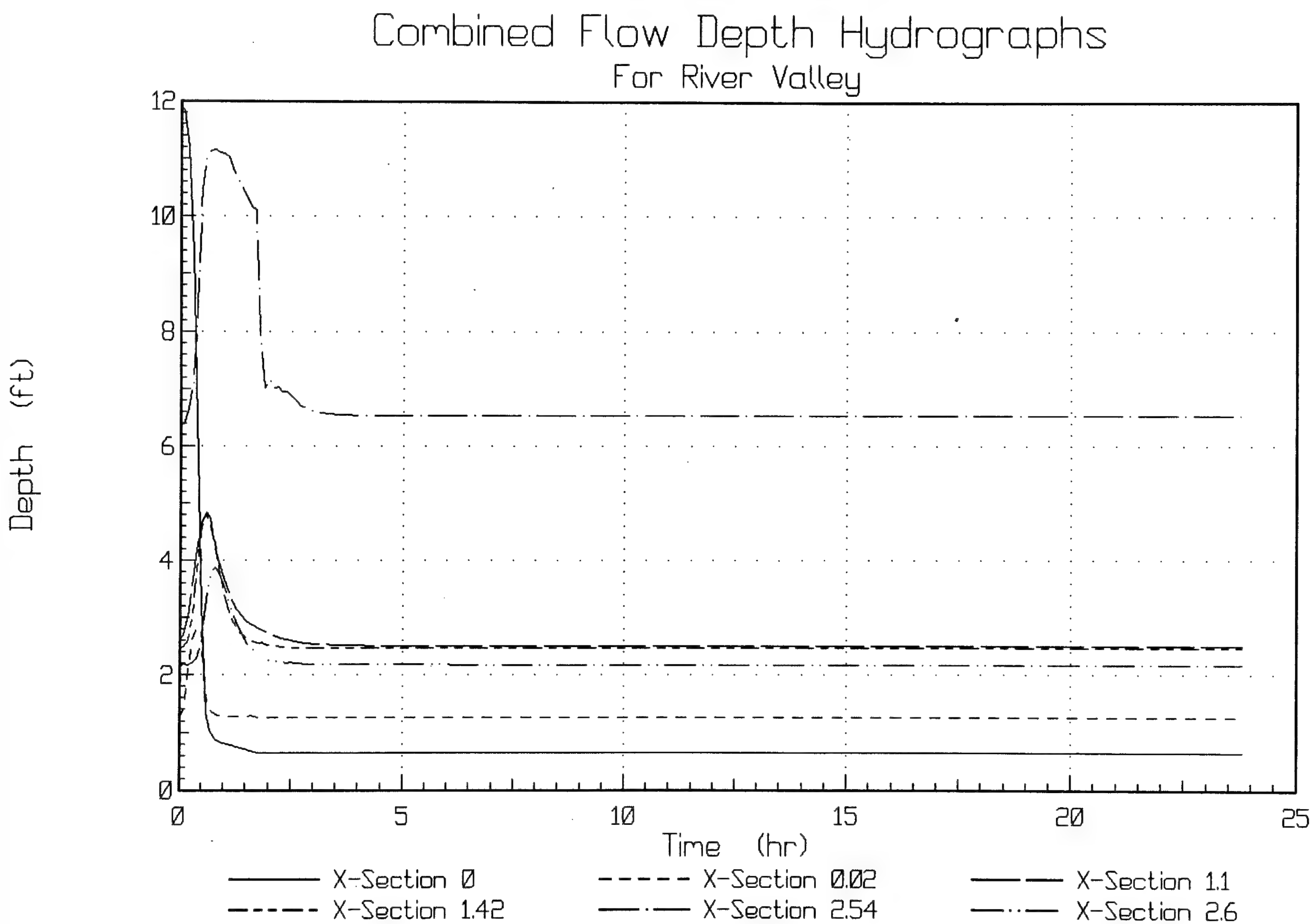


PLATE 10

SUNNY-DAY FAILURE



STORM-DAY FAILURE

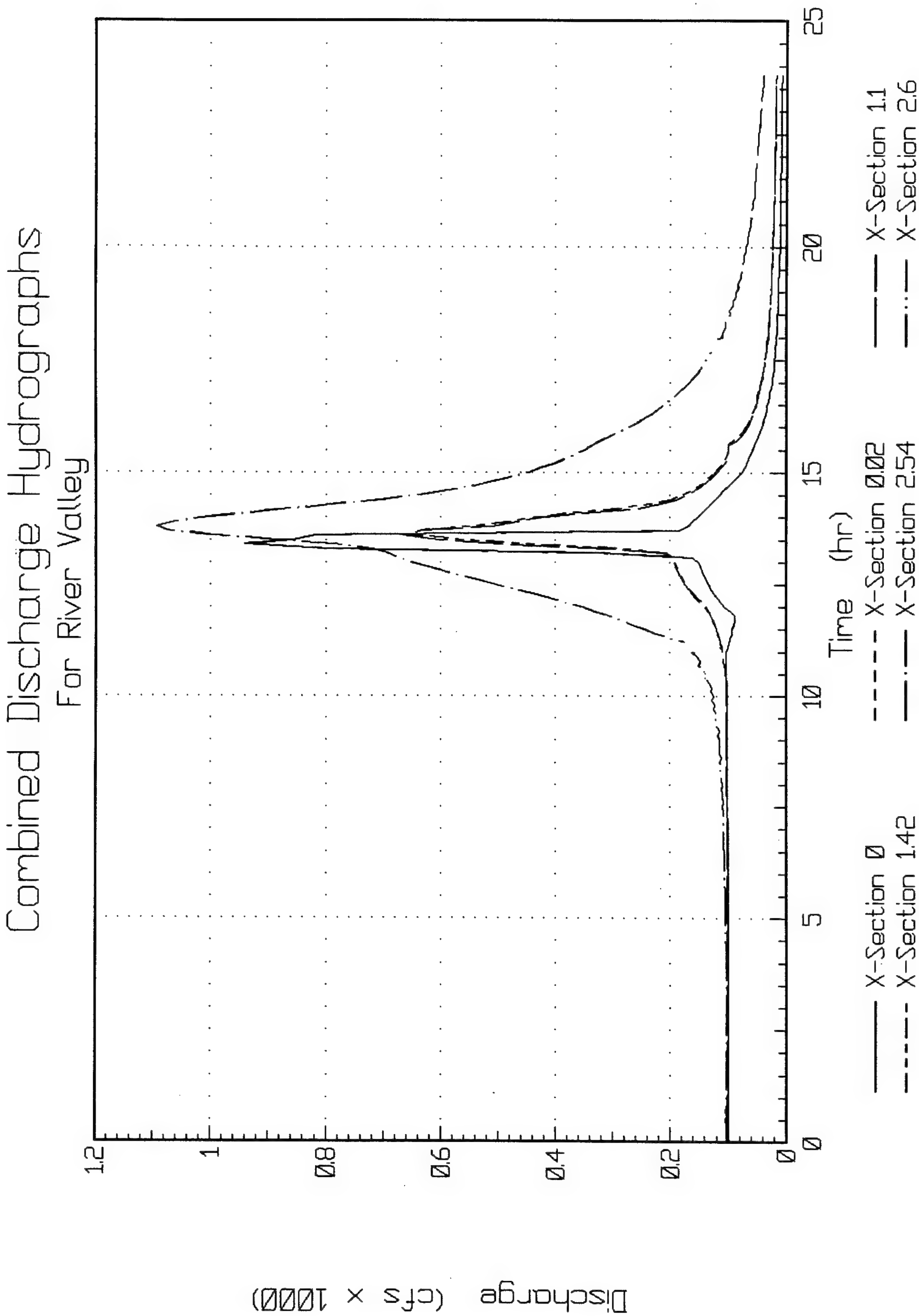
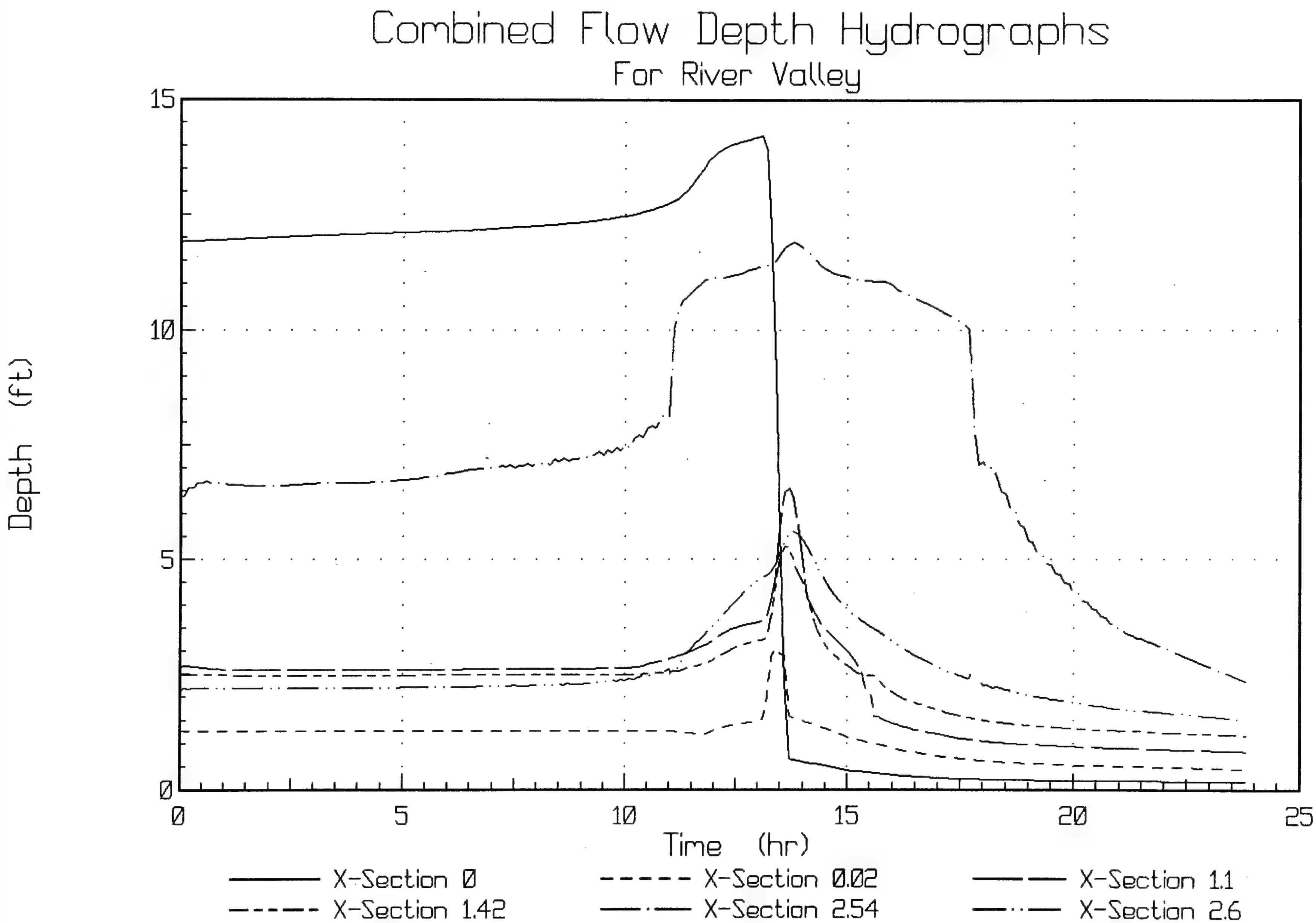


PLATE 12

STORM-DAY FAILURE



EMERGENCY ACTION PLAN
for
UPPER HURRICANE RESERVOIR

1. INTRODUCTION

a. Purpose. This Emergency Action Plan (EAP) is a suggested procedural outline indicating appropriate steps to be taken in the event of an impending failure of Upper Hurricane Reservoir. Also, this EAP lists phone numbers of certain local and state officials to contact in case of an emergency.

b. Items in the EAP. Following are major items which should be addressed by the owner of the dam:

- Monitoring
- Evaluation
- Preventative Action
- Warning

2. MONITORING

a. Purpose. Having a person monitor the dam in the event of an impending failure, is the first step in implementing the EAP. During periods of heavy precipitation, flooding, or any unusual hydrologic event that might cause structural damage to the dam, the owner should have qualified personnel monitor the dam. The owner should assume responsibility for having the monitor at the dam within a reasonable time and for providing an adequate communication system between the monitor and local officials.

b. The designated monitor is:

Name:	Mr. John H. Doe
Address:	Main Street Hartford, Vermont
Phone:	Home: (802) 222-2222 Work: (802) 222-2222

c. Type of Training. The owner should provide proper training so the monitor will have sufficient ability to recognize the condition of the dam and be able to identify and evaluate specific problem area. This training should be extensive enough to allow the monitor to describe conditions to local officials.

d. Communication System. The owner should provide primary

and secondary communication systems between the dam monitor and local officials.

(1) Primary System: Normal telephone communication. The monitor should have access to the nearest available telephone and should have on his person the phone numbers of all appropriate necessary local officials.

(2) Secondary System: Shortwave radio. If the phone system is malfunctioning, the monitor should have access to a shortwave radio that can be monitored by local officials with scanners.

As an alternative to this system, if any local officials live within a short distance of the dam, the monitor could drive to one of their residences if the roads are passable.

3. EVALUATION

a. Purpose. In conjunction with the ability to assess the condition of the dam, the monitor should have the ability to determine and evaluate the nature of any existing problem. This evaluation is a crucial step, because failure to accurately and promptly identify a problem may adversely affect the EAP warning system.

b. Checklist. Following is a check list of items that the monitor should use for assistance in preparing a safety assessment of the dam.

(1) Water Surface Level:

(a) Elevation

Normal
High (If so, how high, with respect to the top of dam?)

(2) Principal Spillway:

(a) Condition on Arrival

Clear
Blocked (If so, to what extent?)

(3) Emergency Spillway

(a) Condition on Arrival

Clear
Blocked (If so, to what extent?)

(4) Top of Dam Crest

(a) Condition on Arrival

Erosion

(5) Downstream Face

(a) Condition on Arrival

Erosion
Evidence of piping

4. PREVENTIVE ACTION

a. Purpose. This section addresses actions that the monitor can take to help prevent an overtopping failure of Upper Hurricane Reservoir dam.

b. The monitor should ensure that the principal and emergency spillways are kept clear of debris during normal conditions. In the event of flood conditions, the monitor should also take reasonable steps to ensure that the spillways do not become blocked with debris so that they can carry their full capacity. Safety of the monitor should not be jeopardized.

5. WARNING

a. Purpose. If the monitor feels that possible failure of Upper Hurricane Reservoir dam is imminent, he should immediately notify the designated parties by utilizing previously established communication systems. The monitor should notify the following officials and the downstream residents. Others can be contacted if determined necessary by the monitor.

b. Officials to Contact (as of September 1994)

(1) Mr. Ralph Lehman
Town Manager - Town of Hartford
Work: (802) 295-9353
Home: (802) 295-2858

(2) Mr. Richard Ballou
Chairman - Town of Hartford Selectmen
Work: (802) 295-9353
Home: (802) 457-1722

(3) Mrs. Deborah Adams
Town Clerk - Town of Hartford
Work: (802) 295-2785
Home: (802) 295-3978

(4) Mr. John Wood, Jr.
Fire Chief - Town of Hartford
Work: (802) 295-3232

(5) Mr. Joseph Estey
Police Chief - Town of Hartford
Work: (802) 295-9425

(6) Vermont Emergency Management Agency
24-Hour Duty Officer
1-800-422-8606
(802) 244-8721

(7) Public Safety Dispatch Center
Local: 911
(802) 295-3725

Officials at the Vermont Emergency Management office can be reached 24 hours a day. During normal business hours, the receptionist at the office will locate the current duty officer. During all other hours, the phone connects to the Vermont State Police Department in Waterbury, which will locate the duty officer. In the event that the phone system fails, any Vermont State Police barracks or cruiser can reach the duty officer through its radio system. Any available shortwave or CB radio can be utilized to contact the nearest police barracks.

c. Downstream Residents. To be filled out and periodically updated by the dam owner.

Name	Phone Number

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